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SELF-INSPECTION OF METHANE EMISSIONS

- A description of the system for inventorying and reducing methane emissions from co-digestion plants, wastewater treatment plants and biogas upgrading plants

Avfall Sverige

Svenskt Vatten

Preface

Biogas is produced through anaerobic digestion of organic material at wastewater treatment plants and co-digestion plants (facilities that carry out anaerobic digestion of different types of organic waste). The absolute majority of the Swedish production of biogas takes place at wastewater treatment plants and co-digestion plants, and an increasing amount of the biogas is also upgraded to the quality required for use as fuel in vehicles. At present, all biogas produced at co-digestion plants and just over 60% of the biogas produced at wastewater treatment plants is upgraded.

Both the production of biogas (raw gas) and the upgrading of biogas can produce emissions, particularly methane. As methane is a strong greenhouse gas, it is important to minimise methane emissions as far as possible. Naturally, it is also important for the plants to minimise emissions since the biogas (methane) generates an income. From a licensing perspective, there is also interest in measuring and minimising emissions as it has become standard practice to set limit values for methane emissions, often linked to percentage of production.

As early as 2007 the Swedish Waste Management Association, Avfall Sverige members started a voluntary system for inventorying methane emissions from biogas and upgrading plants (report U2007:02 in Avfall Sverige's report series). The system has been well disseminated among the co-digestion plants. To broaden the system and get a much larger number of wastewater treatment plants involved Avfall Sverige, and the Swedish Water and Wastewater Association, Svenskt Vatten, have signed a letter of intent regarding co-ownership of the system as of 2018. This updated system description is based on report U2007:02, but has been adapted, inter alia, to better suit wastewater treatment plants and to better describe how the methane emission measurement system relates to the somewhat narrower system boundaries of the sustainability criteria.

Magnus Andreas Holmgren (RISE) has been the project manager and author of this updated system description. Johan Yngvesson, Staffan Carlsson and Daniel Bäckström (all RISE) have also reviewed and provided their viewpoints as part of this work.

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Summary

Atmospheric emissions can arise at different stages of biological treatment through the anaerobic digestion of organic material and in biogas upgrading processes in biogas plants. There are four main reasons why these emissions should be minimised, namely safety aspects, greenhouse gases, finances and odour.

Methane is the combustible component of biogas, and the gas constitutes the bulk of the content, approx. 55–75% by volume. Methane is a greenhouse gas with 34 times greater greenhouse effect than carbon dioxide. This, in combination with safety aspects and finances, make it imperative to reduce methane emissions from a biogas system. Bear in mind that co-digestion of e.g. manure or sludge from wastewater treatment plants reduces the methane emissions that would have otherwise occurred. Depending on which substrate is digested and the intended use of the gas, the methane emissions from the biogas system can be significant before the greenhouse effect becomes equivalent to a reference system with fossil fuels.

In 2007, Avfall Sverige introduced a voluntary undertaking (Avfall Sverige report no. U2007:02), where affiliated plants commit to systematically working to identify and reduce their emissions. This report describes the revised system, which as of 2018 is being run in partnership between Avfall Sverige and Svenskt Vatten.

This report describes how the system is structured for co-digestion plants, wastewater treatment plants, and upgrading plants. It also provides examples of how to remedy any emissions.

Participating plants shall draw up a sketch of the plant that marks out various potential sources of systematic emissions. The methane emissions are then measured and calculated at these spots by an independent measurement consultant. Participating plants shall also carry out systematic leak detection work.

Contents

Appendix 1–2 are also available as an Excel template

1 Introduction

1.1 BACKGROUND

Atmospheric emissions can arise at different stages of biological treatment through the anaerobic breakdown and digestion of organic material and in biogas upgrading processes. There are four main reasons why these emissions should be minimised. These are:

safety aspects	Biogas consists mainly of methane, CH_4, which is a combustible and explosive gas. When the level of methane in the air is 4–16% by volume, the gas mixture may ignite.
prevent greenhouse gas emissions	Methane has a 34 times[1] higher contribution to the greenhouse effect than carbon dioxide. A biogas system may also contain small levels of nitrous oxide, N_2O, also known as laughing gas. This gas contributes about 300 times more to the greenhouse effect than carbon dioxide (Myhre, 2013).
odour problem	Methane is an odourless gas. However, it is likely that methane leakage is accompanied by emissions of other gases, which may have a foul odour. These emissions could cause odour problems, affecting employees and those living nearby.
finances	The plant sells gas or uses the gas internally. Losses through emissions could become costly.

In a 2004 study conducted by SwedPower, emissions were measured at a number of biogas and upgrading plants (Gunnarsson et.al, 2005). In the study, it was determined that the examined plants had small emissions in a number of parts of the plants. Previous emission measurements from upgrading plants also showed that the plants do not always live up to the emissions levels guaranteed by the suppliers (Persson, 2003).

With this in mind, Avfall Sverige introduced a voluntary undertaking for biogas plants in 2007, where the plants commit to working systematically to identify and reduce their emissions. One part of the voluntary undertaking is to regularly measure emissions at the plant to determine methane emissions and methane loss. Another part of the voluntary undertaking is to carry out regular and systematic leak detection work at the plant. The system has been described in two different reports drawn up and revised by Svenskt Gastekniskt Center AB, BioMil AB and Vattenfall Power Consultant AB (Persson et.al, 2007) (Holmgren M., 2009).

In early 2018, Avfall Sverige and Svenskt Vatten signed a letter of intent to jointly run the system under the new name Self-inspection of Methane Emissions, hereinafter referred to as EgMet in this report. This report describes the system, which has now undergone further revision and adaptation e.g. to incorporate the biogas processes of wastewater treatment plants.

1.2 GASES COVERED BY SELF-INSPECTION OF METHANE EMISSIONS

A biogas system is complex, and there can be a variety emissions types from a number of different parts of the system. The focus of Self-Inspections of Methane Emissions (EgMet) is on checking and minimising greenhouse gas emissions, but it also has an indirect effect on other important factors related to emissions, such as safety aspects and finances. Odour problems are also included to a certain extent, as reducing methane emissions can also reduce the emissions of odorants, such as sulphur compounds.

1 According to the latest IPCC report, the value is 34. Previous versions have indicated a value of 25 and 21, respectively. These older values are sometimes still found in current legislation.

The greenhouse gases that may be found in a biogas system are carbon dioxide, methane and nitrous oxide. EgMet focuses solely on methane emissions. A description of the three greenhouse gases in the biogas system and the reason why they are or are not included in EgMet are given here.

Carbon dioxide, CO_2

Carbon dioxide is one of the main components of biogas. Upon combustion of methane, the other main component, carbon dioxide is also formed. Since biogas is a renewable fuel, the carbon dioxide does not produce any net contribution to the greenhouse effect, and it is therefore not included in EgMet.

Methane, CH_4

Over a span of 100 years, methane has about a 34 times greater impact on the greenhouse effect than carbon dioxide (Myhre, 2013). There are large quantities of methane in the biogas system. Since methane is a strong greenhouse gas, it is crucial to minimise methane emissions. With this in mind, methane is included in EgMet.

Nitrous oxide, N_2O

Nitrous oxide can be formed when biogas residue is stored and spread. Based on the limited data on nitrous oxide emissions from biogas plants that is available in the form of measurements and literature, nitrous oxide is currently not included in EgMet. The system owners are currently discussing whether nitrous oxide may be included in the future.

1.3 ENVIRONMENTAL BENEFITS OF BIOGAS SYSTEM

In addition to biogas replacing fossil fuels, the biogas residue produced also reduces greenhouse gas emissions. When biogas residue is used as a fertiliser and replaces mineral fertiliser, more carbon is bound into the soil and emissions from the energy-intensive mineral fertiliser production are avoided. Through production and use of biogas, society's resources are used efficiently. Waste from wastewater treatment, food waste, sludge and the residual products from forestry and industry are utilised and transformed into valuable products – renewable energy and fertiliser. A local circular economy can be fostered, transports reduced, and the need to import energy and fertiliser reduced.

The biogas residue formed during biogas production at co-digestion plants and wastewater treatment plants can be returned to agriculture as an organic fertiliser, provided it is of good quality. Important nutrients are then returned to agriculture and the cycle is closed. The need for mineral fertiliser decreases, as does utilisation of the finite resource phosphorus, which is on the EU's list of critical raw materials. Digestate (biogas residue from co-digestion plants) that contains organic-approved substrates can be used as fertiliser in organic farming, which is important in order to meet the demand for organic food and achieve the political targets set in Sweden's National Food Strategy.

When different biofuels are compared with each other, biogas stands out as the absolute best and the greenest alternative (Börjesson, Tufvesson, & Lantz, 2010). Methane emissions in biogas production are the most important parameter to work with to further improve biogas's climate performance.

1.4 SUSTAINABILITY CRITERIA (SC)

Act (2010:598) on sustainability criteria for biofuels and bioliquids shall ensure that biofuels, e.g. biogas sold as vehicle gas, meet certain sustainability requirements. This means, among other things, implementation of requirements for greenhouse gas emissions reduction, and that the raw material may not be produced in certain lands with high biodiversity and large coal beds. Any party subject to taxation for biogas sold as a fuel (vehicle gas) has a duty to report. Companies that can show that their biogas is sustainable receive tax exemption.

SC reporting includes calculating and reporting methane emissions from biogas and upgrading plants in the production chain. As of 2018, the biogas residue used as fertiliser is defined as a co-product, which means that emissions from biogas residue treatment are not included in the SC system boundary. The various system boundaries are illustrated in figures in chapter 2.1.

1.5 PURPOSE AND GOALS

The purpose of this report is to describe the Self-inspection of Methane Emissions (EgMet) system so that it has good application at both co-digestion plants and wastewater treatment plants, and so that there is a clear connection to SC. The purpose is achieved by:

- describing the EgMet system in terms of its administration and requirements for participating plants
- describing the method for identifying emissions from co-digestion plants, wastewater treatment plants and upgrading plants
- providing examples of methods for remedying any emissions.

The overarching goals of EgMet are to:

- further improve the environmental performance of the biogas system
- give plant owners help in performing a structured inventorying of their plant to detect emissions
- give plant owners better knowledge about the size of the emissions from their plan
- identify and reduce any emissions
- give the biogas industry better information and thereby greater credibility in relation to emissions.

1.6 METHOD

The EgMet system shall be anchored within the biogas industry by actively involving the industry organisation advisory consultants and member company representatives in the work. A joint administrative office shall be established to manage the administration and follow-up of the system.

Project execution team

Magnus Andreas Holmgren, RISE, has been working with the system since the start, with execution of the majority of the methane measurements carried out within the system and with statistical reports and the measurement manual. Johan Yngvesson, Staffan Carlsson and Daniel Bäckström contributed their comments and viewpoints to the work.

Reference team

Carl-Magnus Pettersson, Uppsala TeknikSupport. Develops the gas industry's SC calculation tool.
Tore Sigurdsson, Kristianstads Biogas AB.
Susanne Tumlin, Gryaab. Leader in the development of "Calculation tool for climate impact" for wastewater treatment plants.

Steering committee

Caroline Steinwig, Avfall Sverige's advisory consultant for biological treatment.

Anders Finnson, Svenskt Vatten's advisory consultant for sewer systems, environment and chemical work.

Anneli Andersson Chan, Svenskt Vatten's contact person for SC and EgMet.

1.7 GLOSSARY/DEFINITIONS

Wastewater treatment plant	In the system, it relates to wastewater treatment plants that primarily digest sewage sludge, which results in a reduced volume of sludge as well as biogas production.
Biofilter	Ventilation air is led through filters consisting of soil, compost, LECA balls and/or bark. Contaminants in the air are absorbed in the filter material and broken down by microorganisms. Also referred to as compost filter.
Digestate	Biogas residue produced in a biogas plant that only handles substrates from the feed or food chain, i.e. a co-digestion plant. Most plants of this nature are certified according to SPCR 120.
EgMet	Self-inspection of Methane Emissions. The system described in this report.
SC	Sustainability criteria; see chapter 1.4.
Chemical absorption	Upgrading technique for separating carbon dioxide. It is similar to the water scrubbing technique except that it uses chemicals (either liquid or dissolved in liquid) rather than water to separate the carbon dioxide.
Mineral fertiliser	Mineral fertiliser (e.g. artificial fertiliser, commercial fertiliser, chemical fertiliser) is fertiliser produced through industrial processes.
Normal cubic metre, Nm^3	Volume at 273.15 K (0°C) and 1.01325 bar.
PSA (Pressure Swing Adsorption)	Upgrading technique whereby carbon dioxide adheres to activated carbon under high pressure and detaches when the pressure is lowered.
Residual gas	Carbon dioxide-rich gas that is separated from the biogas in upgrading plants. The gas contains carbon dioxide and low levels of methane. If recirculating water scrubbers are used, the residual gas is diluted in air, and if simple flow-through water scrubbers are used, the residual gas is found in the outgoing water. If Pressure Swing Adsorption (PSA) or chemical absorption is used to separate carbon dioxide, the residual gas is not diluted with air.
Biogas residue	Biogas residue is a collective term for digestate and the digested sludge from a wastewater treatment plant, i.e. the material remaining after the substrate has been digested. Wastewater treatment plants can be certified under the Revaq system in order for the biogas residue to be spread over arable land.
Co-digestion plant	Biogas plant that digests different types of organic material, e.g. source-separated food waste, slaughterhouse waste, manure and energy crops, but not sewage sludge. Hygienisation of the substrate is often found as a requirement.
Manure	Manure is a collective term for faeces, urine, water and litter in various proportions. Manure is categorised as urine, liquid manure, semi-liquid manure, solid manure or deep litter manure depending on its consistency. Liquid manure and urine can be pumped, unlike semi-liquid, solid and deep litter manure. Manure contains nitrogen, phosphorus, potassium sulphur, micronutrients and organic matter that help build up the soil content of the land.
Substrate	The biological material used as a raw material in the digestion process and that bacteria convert to biogas in the process.
Upgrading plant	Plant for upgrading biogas to a methane content of at least 95% (but usually 97–98%) for use as vehicle fuel and/or injection into the gas grid. In the upgrading process, carbon dioxide and other contaminants are separated from the produced biogas (raw gas).
Water scrubbing	Upgrading technique based on carbon dioxide being more soluble in water than methane. The process involves pressurised biogas being led into the bottom of an absorption tower while water is introduced via the top of the tower. When the two meet, the carbon dioxide dissolves in the water.

1.8 LIMITATIONS

This report describes the inventorying of emissions at co-digestion plants, wastewater treatment plants, and upgrading plants. Chapter 2 defines the external system boundary for inventorying of emissions. The EgMet system focuses solely on methane emissions. It applies to all types of plants described in this report.

1.9 PERFORMANCE

EgMet consists of two main parts:

- Systematic leak detection work and remedying of found leaks, primarily performed by the plant's own personnel
- Emission measurement at emission points with systematic emissions to quantify emissions and losses, performed by an external and independent measurement consultant.

Leak detection

Participating plants shall have a procedure for regular and systematic leak detection. A more extensive leak detection inspection shall be performed annually, at which time the entire plant is systematically inspected. Less extensive inspections, i.e. intermediate inspections, shall be performed more frequently, at least once a month, at a number of defined points at the plant. Chapter 3 describes the leak detection methods that can be used and how the work should be performed. Each plant should create a leak detection record for use during leak detection inspections. Example templates for these are found in Appendix 1 and 2. Alternatively, the existing maintenance system can be used. The documentation and procedures shall be reviewed by a measurement consultant in connection with quantification (see below).

Quantification

An external measurement consultant carries out emission measurements and calculations to quantify methane emissions and losses. The measurement consultant follows the measurement and calculation methods described in the current version of the Methane measurement handbook [Handbok metanmätningar] (at the time of this report's publication, the current version is Holmgren, 2016). For each emission point being quantified, the measurement consultant prepares a deviation report, which, inter alia, provides suggestions for reducing emissions. In the quantification record, the emissions are added together to calculate the value of the total methane losses in the plant. Deviation reports and quantification records are included in the reporting from the Excel calculation tool that accompanies the Methane measurement handbook. The measurement consultant submits the deviation reports and quantification records to the plant.

Reporting to the Administrative Office

The plant supplements the qualification record with planned measures to remedy the emissions. Chapter 5 provides a description of some methods for reducing emissions. Finally, the plant specifies in the quantification record its target methane emissions level, which shall be related to the planned measures. The plant then sends the quantification records and deviation reports to the EgMet Administrative Office.

Statistics and knowledge building

The EgMet Administrative Office compiles the results it receives, and this information is sent back to the plants for knowledge building. Information on average emissions from plants in the industry can also be used externally for information purposes. All data that the plants submit to the Administrative Office are handled confidentially, and it will therefore never be possible to relate specific data to individual plants in the material used for external communication.

1.10 INTRODUCTION OF THE SYSTEM

The participation of plants

The voluntary undertaking is concluded between Avfall Sverige/Svenskt Vatten (via the joint Administrative Office) and the plant owner. The documents used for this are found in Appendix 3 and 4. Avfall Sverige and Svenskt Vatten are tasked with informing and asking all of their members whether they want to join the system. Avfall Sverige and Svenskt Vatten shall also actively work to disseminate information about the system to other plants, industry bodies and authorities. The joint Administrative Office shall support the industry organisations in the information work.

Participation fee

Participating plants shall pay an annual fee to cover the expenses of the joint Administrative Office. The amount of the fee shall be determined by Avfall Sverige and Svenskt Vatten and communicated in good time before it is charged.

Leak detection, quantification and reporting to the Administrative Office

Each individual plant procures a measurement consultant who can perform measurements and calculations as described in the Methane measurement handbook. The plant owner shall establish procedures for leak detection at the plant as described in this report.

Documentation in the form of qualification records and deviation reports are submitted to the Administrative Office by the plant owner. This gives Avfall Sverige and Svenskt Vatten feedback from the voluntary undertaking along with data for evaluating the results. The Administrative Office shall keep documentation from the plants confidential. The material can be used to create a compilation that provides a general description of the emissions situation for the industries.

Methane emissions shall be quantified every three years. The documentation must be submitted to the Administrative Office within three months of completing quantification. Leak detection shall be performed regularly. Documentation from leak detection work shall be archived to enable it to be reviewed by the measurement consultant in connection with quantification.

Skills development

Avfall Sverige and Svenskt Vatten shall regularly organise training in the EgMet system for its members. The training activity may include information on methane emissions in general and their impact on the greenhouse effect, a description of different measurement methods, a description of leak detection, quantification of emissions, and a discussion of emission reduction methods. It is desirable for those who work with leak detection and who participate in quantification on behalf of the plant to have participated in relevant training organised by Avfall Sverige and/or Svenskt Vatten.

1.11 CONTINUOUS IMPROVEMENT

The objective is for there to be continuous improvement in participating plants, and for this to observable through decreasing average values over time when the measurement results are compiled and analysed.

2 Description of the system Self-inspection of Methane Emissions system

2.1 SYSTEM BOUNDARIES

The system boundary indicates the external boundary for the emissions from a plant affiliated with EgMet. The system boundary was defined with the following criteria in mind:

- only parts that the plant owner owns/has control over and thereby has the ability to influence shall be included
- only parts related to the production of biogas or refinement/upgrading of gas shall be included; emissions in connection with the use of the gas or biogas residue and emissions in connection with transport of substrate, biogas residue and gas are not included in the system.

The system boundaries indicated in SC deviate somewhat from the system boundaries in EgMet. Both system boundaries are therefore indicated in the figures below.

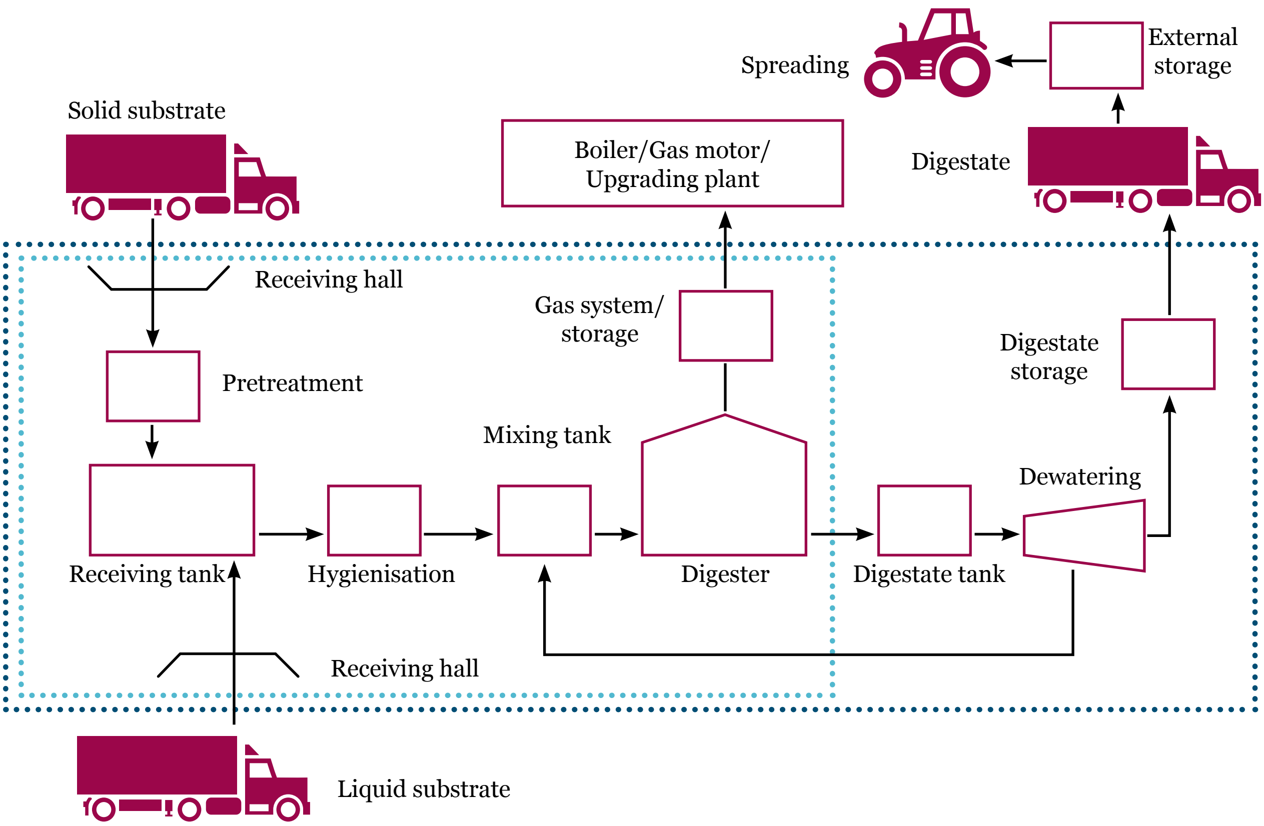
2.1.1 Co-digestion plant

The system boundary for a co-digestion plant is set from the substrate delivery point to the digestate storage vessel at the plant. For substrate, the incoming boundary is when the material is dumped into the hopper for solid material and when the truck is connected for emptying for liquid material. Emissions in connection with transport of substrate to the plant are not included. The outgoing boundary for digestate is when the digestate is pumped from the plant to the truck or into the digestate pipeline. Emissions in connection with digestate transport, storage by the farmer, or spreading on arable land are not included. Co-digestion plants may be designed differently depending on e.g. which substrate is being digested and the choice of pretreatment method. Regardless of exactly which parts are found in the plant, the system includes the entire process from material arrival and pretreatment to its digestion and subsequent storage. For biogas, the outgoing boundary is when the biogas leaves the digester and is directed to the application for use, e.g. a gas boiler or gas motor, or the gas is led to the upgrading plant. The entire gas system of the co-digestion plant, including gas storage vessel, is included.

Figure 1 shows the main components of a co-digestion plant. The light blue line in the figure shows the system boundary for SC. The dark blue line shows the system boundary for EgMet. The dividing line between the two system boundaries is at the first part of the process that is not connected to the gas system[2]. Examples: A post-digester connected to the gas system is handled like a digester and any gas emissions are included in both the SC and the EgMet system boundaries. At plants with joint digestate storage and gas storage, the gas storage vessel is considered part of the gas system, i.e. any emissions from there are included in both the SC and the EgMet system boundaries.

2 With SC, if digestate is used as a fertiliser in agriculture, the digestate is considered a co-product of produced biogas. This means that all emissions after the digester are allocated to the co-product, i.e. to digestate.

Figure 1. System boundaries at a co-digestion plant



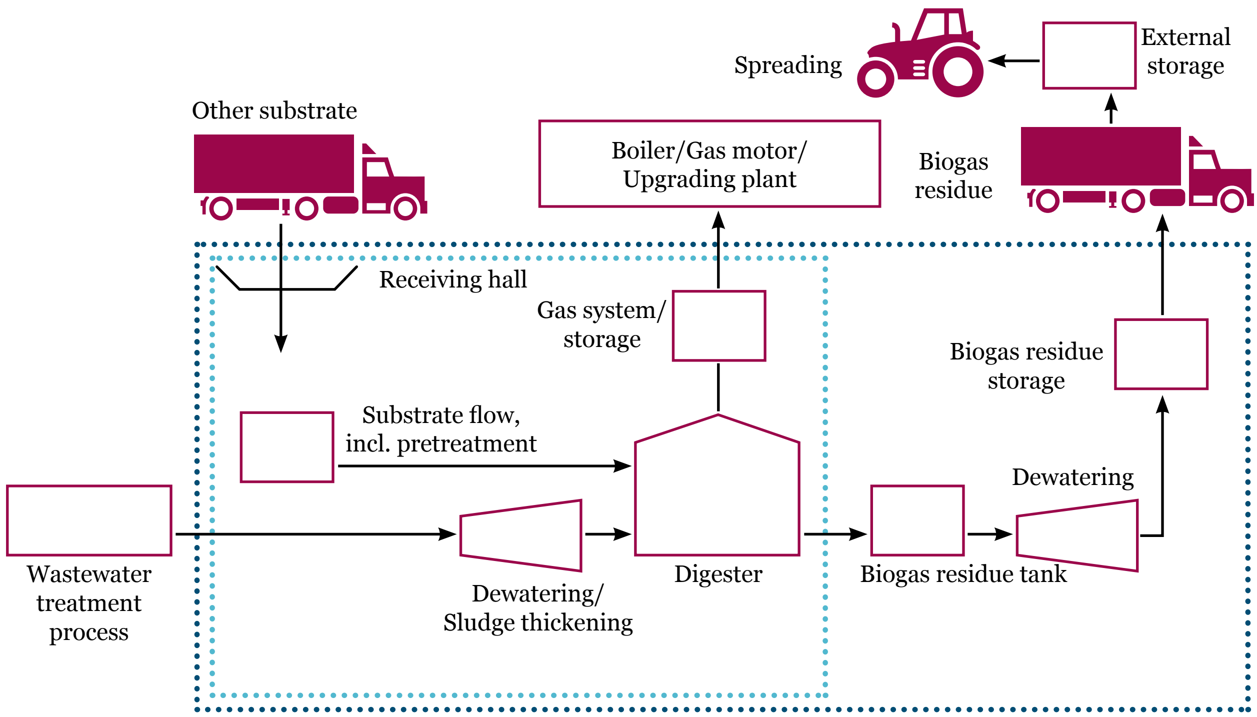
2.1.2 Wastewater treatment plant

The system boundary for a biogas process at a wastewater treatment plant is from the point where digestion sludge flows into the digester, or the point where incoming digestion sludge is treated prior to digestion (e.g. food waste disposals and centrifuges) up to biogas residue storage vessel at the plant. Emissions in connection with the wastewater treatment process are not included. In cases where other substrates are included in the material being digested, all handling from the substrate delivery point (compare with the system boundary for a co-digestion plant) is included. The outgoing boundary for biogas residue is where the biogas residue leaves the plant by truck. Emissions in connection with transport, external storage and the spreading of biogas residue are not included. For biogas, the outgoing boundary is when the biogas leaves the digester and is directed to the application for use, e.g. a gas boiler or gas motor, or the gas is led to the upgrading plant. The entire gas system of the wastewater treatment plant, including gas storage vessel, is included.

Figure 2 shows the main components of a biogas process at a wastewater treatment plant. The light blue line in the figure shows the system boundary for SC. The dark blue line shows the system boundary for EgMet[3]. The dividing line between the two system boundaries is at the first part of the process that is not connected to the gas system[4]. Examples: A post-digester connected to the gas system is handled like a digester and any gas emissions are included in both the SC and the EgMet system boundaries.

3 Storage and handling of biogas residue is done differently at different plants, and which parts of handling and storage should be included in the EgMet system boundary may sometimes be a matter of interpretation.
4 With SC, if biogas residue is used as a fertiliser in agriculture, the biogas residue is considered a co-product of produced biogas. This means that all emissions downstream of the digester or biogas residue tank that are connected to the gas system are allocated to the co-product, i.e. the biogas residue.

Figure 2. System boundaries for a wastewater treatment plant



2.1.3 Upgrading plant

For upgrading plants, the system boundary is set from the point when the raw gas is added to the process (incoming pipeline to the building) to the point where the refined, dried and odourised gas leaves the plant (building).

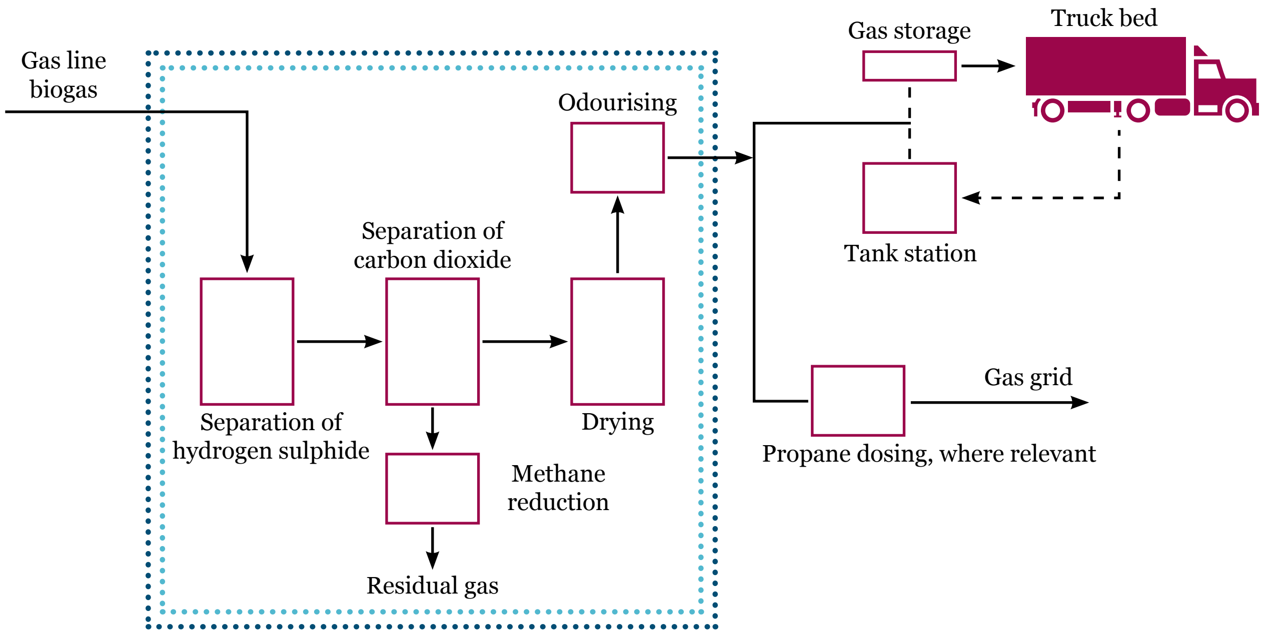
If the gas will be used as vehicle fuel, it is then led to a high-pressure compressor, storage vessel and finally a tank station. If the gas is instead being fed into the gas grid, it is first sent to a propane dosing plant in order to increase the energy content to a level that corresponds to natural gas. High-pressure compression of the biogas, propane dosing, gas storage vessel and tank station are not included in the EgMet system. This is because such plants usually have a different principal than the upgrading plant[5]. Naturally, it is a good idea to introduce equivalent leak detection procedures at such plants as well.

Figure 3 shows the main components of a typical upgrading plant. The light blue line in the figure shows the system boundary for SC. The dark blue line shows the system boundary for EgMet. The boundaries of the two systems are identical for an upgrading plant.

In addition to carbon dioxide, which is separated, the residual gas contains small amounts of methane. Emissions of methane in the residual gas, after any treatment to reduce the methane content, are included in EgMet.

5 It is sometimes difficult to differentiate emissions in the different parts since, for example, the high-pressure compressor may be located in the same premises as the upgrading plant.

Figure 3. System boundary at an upgrading plant



2.2 EMISSION OBJECTS

In the EgMet system, the plant personnel are tasked with identifying possible emission objects with systematic emissions at their plant, and marking them in a sketch or drawing of the plant. To do this, they must have good knowledge of the specific plant. Operations personnel usually have experience with which parts of the plant emissions may or are expected to occur. The plant's classification plans may be a good starting point (see below). The sketch or drawing is reviewed together with the measurement consultant so that they can become familiar with the design of the plant and point out any potential significant emission objects that have been missed. This chapter describes common emission objects in plants, and the information here can be used as support in preparing the sketch.

When identifying the potential emission objects listed in 2.3.1 and 2.3.2, consideration has been given to a plant's classification plan. Classification is a method used to analyse and assess areas where explosive gas mixing may occur during normal operating conditions (SEK, 2017). The choice to apply the classification plan of a biogas plant was made because this makes it possible to quickly get an overview of the areas of the biogas plant where explosive gas mixing may occur. On those occasions when gas exists in a non-classified area, the plant owner should consider revising the classification plan.

2.2.1 Co-digestion plant and wastewater treatment plant

Emission objects that the plant should consider including in the sketch of the plant are found below along with what about the emission object should be given special consideration.

- Ventilation
  Some plants have a single large ventilation system, where multiple subflows are brought together for some form of odour treatment. Other plants have multiple individual ventilation systems in the premises and the process equipment. For all systems, it is the emissions, after any treatment, which shall be determined. In many cases, pretreatment, post-treatment and biogas residue storage vessels are ventilated. Gas equipment rooms are also ventilated, usually individually. Both mechanically ventilated objects and natural ventilation shall be included.

- Mixing tank
  At some plants, there is a mixing tank upstream of the digester. Under unfavourable conditions, such as too much time in the mixing tank, or when process fluid is reintroduced for dilution, the methane formation process starts in the mixing tank. If manure is part of the substrate mix, methane is usually given off from the mixing tank. Methane measurement should be carried out in the venting.

- Digester
  The emission objects on the digester that can be expected to have systematic emissions are the overflow channels, which in some cases open regularly and in other cases are completely open. The post-digester (without active heating) is also part of this object group, as long as produced gas is handled in the gas system.

- Biogas residue tank
  After standing time in the digester, the biogas residue is pumped on to a biogas residue tank, where, by definition, the post-produced gas is not handled in the gas system. This tank may account for a significant proportion of the plant's total methane emissions. If the produced gas is handled, then it is not a biogas residue tank according to the definition applied in this report. It is instead a post-digester (see above).

- Dewatering/thickening
  In some cases, dewatering is connected to a separate or a shared ventilation system, and any methane emissions are then collected and can be determined there. In other cases, any methane emissions are led into the general ventilation of the premises. Dewatering equipment is rarely in continuous operation, so it may be necessary to determine the emissions with and without operation, and calculate the total annual emissions based on number of operating hours.

- Biogas residue storage vessel
  The storage of biogas residue varies between different plants since some only have liquid biogas residue while others have both liquid and solid biogas residue. Moreover, the containers for storing liquid biogas residue vary. At some plants, the biogas residue tank is used for biogas residue storage. At other plants, the biogas residue is pumped from the digester by way of the biogas residue tank and dewatering to the biogas residue storage vessel.

Solid biogas residue is normally stored in an open container or in open spaces, but there are also cases of silo storage, which can be mechanically ventilated or equipped with venting at the top. As with liquid biogas residue, it is conceivable that post-production of methane also occurs in solid biogas residue. The solid biogas residue storage vessel is therefore also included in EgMet.

- Analysis instruments
  There is a continuous gas flow passing through the plant's gas analysers. The methane content of this gas is known, and the flow can usually be read on rotameters that are mounted next to the instruments (common units are lpm (litres/min) and l/h). There are often different subflows through separate analysis instruments.

2.2.2 Upgrading plant

From an emissions perspective, the most important point of an upgrading plant is residual gas. There are continuous methane emissions via residual gas, and it is therefore important to quantify it. The emissions depend on the water or chemical used in the scrubbing technique and the activated carbon in PSA. In addition, carbon dioxide always adsorbs some methane as well.

The emission object for most types of plants is in the point before the residual gas is led to atmosphere. The residual gas can sometimes be led to a treatment plant before being led to atmosphere. In such cases, it is correct to measure the emissions from the treatment plant. For flow-through water scrubbers, the outgoing scrubber water is the emission object. Quantification of methane in residual gas is sometimes complicated, particularly for PSA and simple flow-through water scrubbers (see Methane measurement handbook).

Since residual gas is a known source of methane emissions, one option is to install a meter for continuous measurement of methane levels. This makes it possible to monitor methane emissions with other parameters in the plant and optimise operation for low methane emissions. See chapter 5. In addition to residual gas, the upgrading plant's ventilation should be included since leaks and various emissions in the plant are collected here. There are usually also a number of analysis instruments mounted in the plant. In such cases, the flows through these should also be included in the quantification.

3

Leak detection

In the EgMet system, participating plants shall have a procedure for regular and systematic leak detection. More extensive leak detection work shall be performed annually, at which time the entire plant is systematically inspected. Intermediate inspections shall be performed more frequently, preferably once a month, at a number of defined points at the plant. The leak detection method described in the Methane measurement handbook shall be used.

Good knowledge of the instruments used (how they are used, limitations, what they measure, etc.) is required in order to perform leak detection. It is desirable for the persons participating in leak detection to have undergone training in EgMet. For external inspection, it is possible to hire a measurement consultant to perform the more extensive leak detection, e.g. in connection with the emission measurements every three years. If emission is detected, the exact source must be located as far as possible, and the leak must be remedied immediately if possible.

For each plant that is part of EgMet, a leak detection checklist or equivalent must be established. Appendix 1 and 2 contain sample templates of checklists that can be adapted for each plant. The checklist is used as a record when performing leak detection, and is then archived for later review by a measurement consultant in connection with subsequent emission measurements. It is a good idea to include the checklist in the maintenance system and synchronise it with the plant's maintenance plan.

3.1 METHODS AND INSTRUMENTS

When performing leak detection, methods that provide a qualitative assessment of the condition of the plant and that quickly detect emissions shall be used. Common methods are traditional leak detection instruments (for flammable gas), leak detection spray, and visual and odour checks. For EgMet, leak detection procedures based on leak detection instruments are required. Leak detection spray can be a valuable supplement, particularly during maintenance work.

Leak detection instruments for methane can be based on different measurement methods. Common methods are semiconductor sensors or catalytic sensors. It is important to distinguish between leak detection instruments and gas detectors. Leak detection instruments present measurement results as a level on a display. Moreover, it must be possible to fit a measuring probe on the instrument (see figure on the left in Figure 4) in order to check difficult-to-reach spaces. The detection limit for methane shall be 5 ppm or lower to be acceptable within the EgMet system.

Figure 4. Leak detection instruments. An instrument with semiconductor sensor is shown on the left, and one with a catalytic sensor is shown on the right.

Source: www.ppm-teknik.se and photo SGC.

Leak detection spray or regular soapy water is mainly used for checking the tightness of flange joints and other joints. During use, leak detection spray is applied to e.g. a flange joint. If the flange joint is not tight, the sprayed layer will begin to bubble. A visual and/or odour check means that emissions are detected by means of the personnel's eyes and nose. If hot gas is discharged, there will be a damp spot on the component. If cold gas is discharged, the component will be icy cold. After it rains, it is a good idea to check flat surfaces, e.g. concrete roof, horizontal manhole covers and the shaft attachment of the stirrer. If there are leaks, this will be seen through bubbles in the rainwater.

A more advanced leak detection instrument that has become more common is the optical gas imaging (OGI) camera, which is an IR camera adapted to display methane emissions on the screen. With such a camera, it is possible to perform leak detection in large plants relatively quickly and identify significant leaks. OGI cameras can be a valuable method during the annual extensive leak detection inspection. Intermediate inspections should primarily be based on traditional leak detection instruments.

An extensive leak detection inspection shall be performed at least once a year, at which time the entire plant is systematically inspected. The leak detection should be performed in accordance with a checklist/record that is based on the templates provided in this report and has been adapted to suit the specific plant. The extensive leak detection inspection shall be supplemented with intermediate inspections in number of predefined points; preferably once a month. The leak detection method described in the Methane measurement handbook shall be used.

The leak detection instrument shall present measurement results as a level on a display. It should be possible to fit a measuring probe on the instrument, and it should have a methane detection limit of 5 ppm or lower.

4 Emission measurement and calculation

In the EgMet system, the plants are required to carry out quantification of methane emissions at least once every 3 years. The emission measurement and calculation method described in the Methane measurement handbook shall be used. The measurement shall be carried out by an independent measurement consultant. As a minimum, the scope of the reporting shall correspond to that given when reporting using the Excel template that accompanies the Methane measurement handbook. When carrying out the measurement, the measurement consultant shall also check that procedures and completed leak detection investigations are documented as indicated in chapter 3. This check shall be documented in the measurement consultant's report.

It is worth noting that it can be a challenge to determine annual emissions from digestate storage/biogas residue storage. One issue is that it is often difficult in terms of measurement technique to find a representative instantaneous value in connection with carrying out the measurement work. For completely open storage, measurements must be taken at a sufficient number of points to obtain a representative average. It may also be necessary to take the different ages of the stored material into consideration. Moreover, there are great uncertainties in how instantaneous data can be extrapolated to annual emissions. Influencing factors can be season, substrate, conversion in storage, etc. There may be a development need in relation to these issues.

Quantification of methane emissions shall be carried out at least once every 3 years. The emission measurement and calculation method described in the Methane measurement handbook shall be used.

5

Methods for remedying emissions

There is continuous emission of methane at biogas and upgrading plants. To reduce the emissions, they must be remedied with reasonable resources within a reasonable amount of time. Suggestions of common measures are presented below.

5.1 METHODS FOR REDUCING EMISSIONS FROM BIOGAS PLANTS

At biogas plants, valves, particularly moving valves and safety valves on digesters and post-digestion storage vessels, are often a problem from an emissions perspective. Undesired emissions from valves are remedied by replacing the gasket and/or spindle. The seal around manholes and the shaft fastener of the stirrer shall be repaired as necessary. The seal can be replaced in connection with complete emptying of the digester.

The most critical emission objects at a biogas plant are the parts that are not connected to the plant's gas system but can nonetheless have methane emissions. A few examples are provided below:

Methane formation upstream of the digester

Receiving tanks and buffer tanks for fresh substrate are normally dimensioned for receiving and storing substrate to enable continuous operation over, for example, the end of the week and long weekends. This means that the receiving system has a standing time of several days. If the plant is run with low capacity, the standing time in the receiving tanks may be so long that methane formation starts. This is especially true in the summer when temperatures are high.

If methane formation occurs in receiving tanks, this leads to direct emission of methane from the tanks. In addition, substrate is normally pumped from the receiving system to the hygienisation tanks, where it is heated and stirred with a stirrer. This means that the methane is also released in the hygienisation tanks.

From hygienisation, the substrate is pumped to the digester. In some cases, there is an intermediate step where the substrate goes to a buffer or mixing tank that is connected to the plant's ventilation system. Under unfavourable conditions, such as too much time in the mixing tank, or when process fluid is reintroduced for dilution, the methane formation process can start in the mixing tank. To reduce methane loss, the temperature in the mixing tank should be constantly low, below 17°C, i.e. a temperature lower than the methane builders require. Dilution with process fluid with a high level of microorganisms should also be avoided.

Any emissions of methane from the process parts described above should be treated in ventilation air (e.g. through combustion). Connecting the air flows to the plant's gas system cannot be recommended from a gas safety perspective.

Digester

The safety valve on the top of the digester should open at overpressure in the digester. If the safety valve opens frequently, it may mean that the valve is incorrectly adjusted (fluid level is too low in the safety vessel). It could also be due to variations in the gas production if the substrate pumped into the digester is not of a uniform quality and the digestion process is thereby "thrown off balance".

In older digesters at wastewater treatment plants, it is common for the overflows to be vented. The methane emissions in such vents can be significant and amount to several percent of the gas production. A simple measure to prevent such emissions is to install a water trap or similar device.

Biogas residue

Downstream of the digester, the methane formation process continues in the biogas residue. The most suitable way to handle the gas from the biogas residue is to keep it in a closed biogas residue storage vessel that is connected to the gas system. Here, the biogas residue can be allowed to cool and the methane formed taken care of.

For plants with open handling of biogas residue, both solid and liquid, there are two methods to reduce emissions. One alternative is to enclose handling so it is in a closed space and then connect this to the plant's gas system (as described above). If closed handling is not possible, the biogas residue's standing time in post-digestion storage can be increased, provided that the storage is gas-tight.

One way of ensuring that methane production in the biogas residue has decreased is to lower the temperature of the biogas residue since methane production decreases at temperatures below 17°C. This can be done through heat exchange/heat pump or by mixing in an amount of cold material. The methane formation process can also be inhibited by adding oxygen, e.g. through regular stirring in the storage vessel. Post-hygienisation, i.e. hygienisation of biogas residue/digestate, is another effective method for preventing methane production in the biogas residue.

Flaring

To achieve the lowest possible emissions during flaring of excess gas, a high temperature flare (approx. 1100°C) is recommended. Another way to reduce methane emissions during flaring is to use an adjustable flare to prevent an unnecessary amount of gas from being flared. Methane emissions can also occur if the gas/air mixture ratio is incorrect.

5.2 METHODS FOR REDUCING EMISSIONS FROM UPGRADING PLANTS

Valves are a recurring emission object at upgrading plants as well. Flange joints on pipes with some movement should be tightened regularly. For compressors, regular maintenance is important to reduce methane emissions.

If measurements at an upgrading plant indicate high methane losses through the residual gas from the plant, the primary measure should be to try to adjust the plant; see the section below. If the results of this are insufficient, methods for destroying the residual gas may be considered.

Plant adjustment

In an upgrading plant using the water scrubbing technique, carbon dioxide is separated through pressurised water absorption. The principle is based on carbon dioxide being more soluble in water than methane. The separation takes place by pressurised raw gas being supplied in the bottom of an absorption column and meeting counterflowing water that is pumped in from the top. Methane has some solubility in water. By not running the absorption of carbon dioxide in the scrubber tower too long, a smaller amount of methane is absorbed in the water. From a methane loss perspective, it is more beneficial to upgrade to 96% methane than 98% in the purified gas.

The remaining steps then differ depending on the type of water scrubber plant. For a recirculating water scrubber, the water continues to a desorption column. If there is high methane loss in the outgoing residual gas from the desorption column, the pressure in the flash tank should be lowered. If this is not enough, the plant's settings should be reviewed so that they match the dimensioning. For a simple flow-through water scrubber plant, the water goes to a recipient or drain. If there is high methane loss in the outgoing water, the same measures as for a recirculating water scrubber apply.

In a PSA plant, carbon dioxide is separated through adsorption of activated carbon or zeolites. The process normally consists of six pressurised columns that work cyclically relative to each other. Switching between the cycle's various processes, adsorption and desorption (negative pressure, pressure equalisation and blow-out) takes place by means of a timed valve system. The columns are regenerated through stepwise pressure reduction, where the adsorbing molecules release from the adsorption material. The adsorbing molecules are mainly carbon dioxide and a small amount of methane. Final regeneration takes place with a vacuum pump. Since the residual gas from this step contains a small amount of methane, the number of final regeneration occasions should be reduced. This can be done by adjusting the plant's timed valve system and thereby increasing the degree of saturation in the adsorption columns.

In an upgrading plant with chemical absorption, the methane loss in normal operation is already low since the absorbent is selective for, inter alia, carbon dioxide and the working pressure is low. Chemical absorption produces better carbon dioxide separation in relation to the aforementioned upgrading techniques. By ensuring the plant settings are in line with the dimensioning, it should be possible to keep the methane loss low.

Destruction of residual gas

For upgrading techniques that receive the residual gas in a gas stream, it is possible to oxidise and thereby destroy the methane. Since the methane content in the residual gas is low, it is not possible for self-sustaining combustion to take place in a conventional gas boiler with only the residual gas as fuel. For methane, the lower explosion limit, i.e. the lower limit for ignition and self-sustaining combustion, is 5.3% by volume in air. If the residual gas is being combusted in a conventional gas boiler, support fuel, such as biogas, is required. In recirculating water scrubber plants, the residual gas is diluted in a large volume of air. One possibility is to use this air as combustion air for a gas boiler. A common problem here is that the residual gas has larger flows than required as combustion air for the boiler for heating the biogas plant, making this not applicable in practice. The combustion of residual gas from PSA plants in a gas boiler is more suitable as the residual gas has not been diluted with air.

In addition to a conventional boiler, there are other methods of oxidising methane. The oxidation can be either thermal or catalytic. There are a few examples of thermal destruction of the methane in residual gas from upgrading plants in Sweden. Methods of oxidising methane through thermal oxidation, flameless oxidation and catalytic oxidation are described here. All of these methods are relatively costly, with an investment cost in the neighbourhood of one half to one million Swedish krona.

Regenerative thermal oxidation (RTO)

Regenerative thermal oxidation of methane involves the use of a bed of ceramic material. To start the process, the bed is heated to 950°C with an electric heater. The residual gas is then led into the bed. The gas is heated by the ceramic material and the methane is oxidised with oxygen to carbon dioxide and water. When the gases are led out of the bed, they emit heat to the ceramic material. The hottest zone in the bed is displaced in the direction of the flow. To ensure high efficiency in the heat exchange and prevent overheating of the material, the flow is reversed after a period of time. This is the regenerative principle; that energy from the exhaust gases is stored in the material and then used to heat the incoming gas flow.

The system makes it possible to reduce methane by 98%. Electric heating is required to start the system. A methane content of 0.1–0.2% by volume is then required for the process to be self-sustaining. If the methane content drops below this value, additional energy in the form of electricity or gas is required. The methane content may not exceed 25% of the lower explosion limit, i.e. approximately 1.3% by volume of methane. If there is a risk of the methane content exceeding this limit on certain occasions, the gas can be diluted with air. The addition of air is always required if the residual gas does not contain air (e.g. residual gas from PSA). If hydrogen sulphide is present in the residual gas, it is oxidised to sulphur dioxide, SO_2.

The regenerative thermal oxidation method is well known and is used, inter alia, in industry for the oxidation of volatile organic compounds (VOC), particularly hydrocarbons, in process air or for oxidising methane when extracting coal in mines. In these processes, the volume flows are usually as large as 1,000 to 110,000 Nm^3 per hour. However, the method can also be used for smaller flows.

Flameless oxidation (FLOX)

Flameless oxidation is based on heat exchange between the combustion air and the exhaust gases via a ceramic material. Alternating air and exhaust gases pass in the ceramic material, giving rise to regenerative heat exchange. The severe preheating of the combustion air makes it possible to achieve self-sustaining combustion using a fuel with a lower heating value than would otherwise be possible. Biogas is used to start the burner with flame. When a sufficient temperature is reached, the burner switches to FLOX mode, and the residual gas is combusted with air at 950°C. Biogas is only used to start the burner. Otherwise, the combustion should work with residual gas alone. In principle, all methane in the residual gas is oxidised in the burner. The exhaust gases can be used to heat water that can be used as part of the heating of the biogas plant.

Catalytic oxidation

Another method that can be used to destroy the methane in the residual gas is catalytic oxidation, where methane oxidation takes place on the catalyst surface. The catalyst reduces the activation energy of the reaction. As a result, methane can oxidise at a lower temperature and a higher methane content is therefore required for self-sustaining combustion. The active substance in the catalyst can consist of platinum (Pt), palladium (Pd) or cobalt oxide. As with the previously described methods, the addition of energy in the form of electricity or support fuel is required in order to achieve the initial conditions. A methane content of 0.25% by volume is then required for the process to be self-sustaining. The material can be damaged by hydrogen sulphide, which must be taken into account. The catalytic oxidation reduces the methane content by over 90–95% depending on the amount of catalyst.

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B Appendices

APPENDIX 1. LEAK DETECTION RECORD
– CO-DIGESTION PLANT AND WASTEWATER TREATMENT PLANT

1. Potential emission object	2. Was methane leakage detected? YES	NO	3. Enter measure-ment (if any)	4. Specify type of action
DIGESTER				
Safety valve				
Water trap and collection tank				
Dynamic valves				
Static valves				
Roof				
In the sealing strip of hatches on the roof (e.g. manhole)				
Transition between wall and roof				
Overflow channels				
BIOGAS RESIDUE STORAGE VESSEL				
Safety valve on biogas residue tank				
Water trap on biogas residue tank				
Dynamic valves on biogas residue tank				
Static valves on biogas residue tank				
Roof on biogas residue tank (especially if it is a concrete roof)				
In the sealing strip of hatches on the roof (e.g. manhole)				
Transition between wall and roof				
CONDENSATE SYSTEM				
Condensation vessel/condensation reservoir				
Condensate drain				
GASOMETER				
Liquid gasometer: roof				
Liquid gasometer: at edge between wall and room				
Double membrane gasometer: at air outlet				
GAS TORCH				
Valves on aboveground pipes to torch				
Flange joints on aboveground pipes to torch				
GAS EQUIPMENT ROOM				
Sludge trap/or				
Gas filter				
Compressor				
Gas booster				
Dynamic valves				
Static valves				
Safety valve				
Water trap				
Flange joints on movable pipes				
Analysis instruments				
OTHER				

Appendix 1 is also available as an Excel template

APPENDIX 2. LEAK DETECTION RECORD – UPGRADING PLANT

1. Potential emission object	2. Was methane leakage detected? YES	NO	3. Enter measurement (if any)	4. Specify type of action
MOVING COMPONENTS (in shaking spaces or regular movement)				
Control valves on movable gas line				
Manual valves on movable gas line				
Flange joints on movable gas line				
Compressors				
NON-MOVING COMPONENTS				
Control valves on non-movable gas line				
Valves on incoming raw gas line				
Manual valves on non-movable gas line				
Flange joints on non-movable gas line				
Gas analysis equipment				
Safety valve				
Ventilation				

Appendix 2 is also available as an Excel template

APPENDIX 3. REGISTRATION FORM – CO-DIGESTION PLANT AND WASTEWATER TREATMENT PLANT

Downloadable from the web-pages: www.avfallsverige.se or www.svensktvatten.se

APPENDIX 4. REGISTRATION FORM – UPGRADING PLANT

Downloadable from the web-pages: www.avfallsverige.se or www.svensktvatten.se

APPENDIX 5. RESIGNATION FORM

Downloadable from the web-pages: www.avfallsverige.se or www.svensktvatten.se

Avfall Sverige is the municipalities' trade association in the field of waste management and recycling. Avfall Sverige's members ensure that waste is collected and recycled in all Swedish municipalities. We perform our work on behalf of society: in an environmentally sound, sustainable and long-term manner.
Our vision is "Zero Waste". We are taking action to minimise waste, promote reuse and ensure that the waste produced is recycled, recovered and managed in the optimal manner. Municipalities and their enterprises are the ambassadors, catalysts and guarantors of this change.

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